CLAIMS

What is claimed is:

1. A droplet ejection apparatus comprising:

a plurality of droplet ejection heads, each of the droplet ejection heads including:

a diaphragm;

an actuator which displaces the diaphragm;

a cavity filled with a liquid, an internal pressure of the cavity being increased and decreased in response to displacement of the diaphragm; and

a nozzle communicated with the cavity, through which the liquid is ejected in the form of droplets in response to the increase and decrease of the internal pressure of the cavity;

a driving circuit which drives the actuator of each droplet ejection head;

residual vibration detecting means for detecting a residual vibration of the diaphragm displaced by the actuator after the actuator has been driven by the driving circuit;

pulse generating means for generating reference pulses;

computation means for carrying out a computation for the number of reference pulses generated by the pulse generating means on the basis of the residual vibration of the diaphragm detected by the residual vibration detecting means;

time measuring means for measuring a lapsed time since the actuator has been driven by the driving circuit; and

head failure judging means for judging a head failure in the droplet ejection heads on the basis of the computation result of the computation means and the lapsed time measured by the time measuring means.

2. A droplet ejection apparatus comprising:

a plurality of droplet ejection heads, each of the droplet ejection heads including:

a cavity filled with a liquid;

a nozzle communicated with the cavity; and

an actuator which changes an internal pressure of the cavity to eject the liquid in the form of droplets through the nozzle in response to the pressure changes;

a driving circuit which drives the actuator of each droplet ejection head;

residual vibration detecting means for detecting a residual vibration of an electromotive voltage generated from the actuator after the actuator has been driven by the driving circuit;

pulse generating means for generating reference pulses;

computation means for carrying out a computation for the number of reference pulses generated by the pulse generating means on the basis of the residual vibration of the electromotive voltage detected by the residual vibration detecting means;

time measuring means for measuring a lapsed time since the actuator has been driven by the driving circuit; and

head failure judging means for judging a head failure in the droplet ejection heads on the basis of the computation result of the computation means and the lapsed time measured by the time measuring means.

3. The droplet ejection apparatus as claimed in claim 1 or 2, wherein the computation means includes timing generating means for generating predetermined timing on the basis of the residual vibration detected by the residual vibration detecting means, a counter which counts the number of reference pulses generated by the pulse generating means for a predetermined time period, and holding means which holds the count value of the counter at the timing generated by the timing generating means.

4. The droplet ejection apparatus as claimed in claim 3, wherein the counter subtracts the number of reference pulses generated for the predetermined time period from a predetermined reference value.

5. The droplet ejection apparatus as claimed in claim 4, further comprising a memory for storing the predetermined reference value.

6. The droplet ejection apparatus as claimed in claim 4, further comprising a temperature sensor for measuring ambient temperature of the plurality of droplet ejection heads.

7. The droplet ejection apparatus as claimed in claim 6, wherein the predetermined reference value is corrected on the basis of the ambient temperature measured by the temperature sensor.

8. The droplet ejection apparatus as claimed in claim 3, wherein the predetermined time period is a time period until the residual vibration is generated after driving the actuator.

9. The droplet ejection apparatus as claimed in claim 3, wherein the predetermined time period is a time period corresponding to a first half cycle of the residual vibration.

10. The droplet ejection apparatus as claimed in claim 3, wherein the predetermined time period is a time period corresponding to a first one cycle of the residual vibration.

11. The droplet ejection apparatus as claimed in claim 1 or 2, wherein the head failure judging means judges presence or absence of the head failure in the droplet ejection heads and a cause thereof on the basis of the computation result by the computation means and the lapsed time.

12. The droplet ejection apparatus as claimed in claim 3, wherein the head failure judging means judges a cause of the head failure on the basis of the count value held by the holding means and the lapsed time.

13. The droplet ejection apparatus as claimed in claim 12, wherein the head failure judging means judges that an air bubble has been intruded into the cavity as the cause of the head failure in the case where the held count value is larger than a first count threshold.

14. The droplet ejection apparatus as claimed in claim 12, wherein the head failure judging means judges the cause of the head failure according to the lapsed time in the case where the held count value is smaller than a first count threshold.

15. The droplet ejection apparatus as claimed in claim 14, wherein the head failure judging means judges that much paper dust is adhering in the vicinity of the outlet of the nozzle as the cause of the head failure in the case where the held count value is smaller than a third count threshold and the lapsed time is smaller than a first time threshold.

16. The droplet ejection apparatus as claimed in claim 14, wherein the head failure judging means judges that little paper dust is adhering in the vicinity of the outlet of the nozzle as the cause of the head failure in the case where the held count value is in the range between a second count threshold and a third count threshold and the lapsed time is smaller than a first time threshold.

17. The droplet ejection apparatus as claimed in claim 14, wherein the head failure judging means judges that the head failure does not occur in the case where the held count value is in the range between the first count threshold and a second count threshold and the lapsed time is smaller than a first time threshold.

18. The droplet ejection apparatus as claimed in claim 14, wherein the head failure judging means judges that much paper

dust is adhering in the vicinity of the outlet of the nozzle as the cause of the head failure in the case where the held count value is smaller than a third count threshold and the lapsed time is in the range between first and second time thresholds.

19. The droplet ejection apparatus as claimed in claim 14, wherein the head failure judging means judges that the liquid in the vicinity of the nozzle has somewhat thickened due to drying as the cause of the head failure in the case where the held count value is in the range between a second count threshold and a third count threshold and the lapsed time is in the range between first and second time thresholds.

20. The droplet ejection apparatus as claimed in claim 14, wherein the head failure judging means judges that the head failure does not occur in the case where the held count value is in the range between the first count threshold and a second count threshold and the lapsed time is in the range between first and second time thresholds.

21. The droplet ejection apparatus as claimed in claim 14, wherein the head failure judging means judges that the liquid in the vicinity of the nozzle has considerably thickened due to drying as the cause of the head failure in the case where the held count value is smaller than a third count threshold and the lapsed time is larger than a second time threshold.

22. The droplet ejection apparatus as claimed in claim 14, wherein the head failure judging means judges that little paper dust is adhering in the vicinity of the outlet of the nozzle as the cause of the head failure in the case where the held count value is in the range between a second count threshold and a third count threshold and the lapsed time is larger than a second time threshold.

23. The droplet ejection apparatus as claimed in claim 14,

wherein the head failure judging means judges that the head failure does not occur in the case where the held count value is in the range between the first count threshold and a second count threshold and the lapsed time is larger than a second time threshold.

24. The droplet ejection apparatus as claimed in claim 11, further comprising recovery means for carrying out recovery processing to eliminate the cause of the head failure judged by the head failure judging means.

25. The droplet ejection apparatus as claimed in claim 24, wherein the recovery means includes: wiping means for carrying out a wiping process in which a nozzle surface of the plurality of droplet ejection heads where the nozzles are arranged is wiped with a wiper; flushing means for carrying out a flushing process by which the droplets are preliminarily ejected through the predetermined nozzle by driving the actuator; and pumping means for carrying out a pump-suction process with the use of a pump connected to a cap that covers the nozzle surface of the plurality of droplet ejection heads.

26. The droplet ejection apparatus as claimed in claim 25, wherein the recovery means carries out the flushing process or the pump-suction process in the case where it is judged that the cause of the head failure is the little thickening of the liquid due to drying.

27. The droplet ejection apparatus as claimed in claim 25, wherein the recovery means carries out the pump-suction process in the case where it is judged that the cause of the head failure is the considerable thickening of the liquid due to drying.

28. The droplet ejection apparatus as claimed in claim 25, wherein the recovery means changes the number of ejections in the flushing process or a suction time of the pump in the

pump-suction process according to the degree of the thickening of the liquid due to drying and carries out the flushing process or the pump-suction process in the case where it is judged that the cause of the head failure is the thickening of the liquid due to drying.

29. The droplet ejection apparatus as claimed in claim 25, wherein the recovery means carries out the wiping process in the case where it is judged that the cause of the head failure is the adhesion of paper dust.

30. The droplet ejection apparatus as claimed in claim 25, wherein the recovery means changes the number of wiping operations in the wiping process according to the degree of the adhesion of paper dust and carries out the wiping process in the case where it is judged that the cause of the head failure is the adhesion of paper dust.

31. The droplet ejection apparatus as claimed in claim 25, wherein the recovery means changes the number of wiping operations in the wiping process according to the degree of the ejection operations in the flushing process in response to the lapsed time and carries out the flushing process in the case where it is judged that the cause of the head failure is the little thickening of the liquid due to drying when the flushing process is to be carried out.

32. The droplet ejection apparatus as claimed in claim 25, wherein the recovery means carries out the pump-suction process in the case where the cause of the head failure is the intrusion of air bubble.

33. The droplet ejection apparatus as claimed in claim 25, wherein the recovery means changes a suction time of the pump in the pump-suction process according to the computation result and carries out the pump-suction process in the case where it

is judged that the cause of the head failure is the intrusion of air bubble.

34. The droplet ejection apparatus as claimed in claim 24, wherein the recovery means carries out the recovery processing until the cause of the head failure judged by the head failure judging means is eliminated.

35. The droplet ejection apparatus as claimed in claim 24, further comprising:

informing means for informing that the head failure is not recovered in the case where the cause of the head failure is not eliminated even though the recovery means carried out the recovery processing.

36. The droplet ejection apparatus as claimed in claim 35, further comprising:

liquid storage means for storing the liquid to be supplied to the cavities of the plurality of droplet ejection heads, wherein the informing means informs that the liquid storage means is to be exchanged in the case where the cause of the head failure is not eliminated even though the recovery means carried out the recovery processing.

37. The droplet ejection apparatus as claimed in claim 24, wherein the droplet ejection apparatus is constructed so as to stop a printing operation when carrying out a printing operation in the case where the cause of the head failure is not eliminated even though the recovery means carried out the recovery processing.

38. The droplet ejection apparatus as claimed in claim 1 or 2, further comprising storage means for storing the judgment result judged by the head failure judging means in association with the nozzle for which the judgment was carried out.

39. The droplet ejection apparatus as claimed in claim 1 or 2, further comprising:

switching means for switching a connection of the actuator from the driving circuit to the residual vibration detecting means after carrying out the droplet ejection operation by driving the actuator.

40. The droplet ejection apparatus as claimed in claim 39, wherein the droplet ejection apparatus comprises a plurality of residual vibration detecting means, a plurality of computation means, a plurality of head failure judging means and a plurality of switching means;

wherein the switching means corresponding to the droplet ejection head in which the actuator has carried out the driving operation switches the connection of the actuator from the driving circuit to the corresponding residual vibration detecting means, and then the head failure judging means corresponding to the switched residual vibration detecting means judges the head failure of the corresponding droplet ejection head.

41. The droplet ejection apparatus as claimed in claim 1 or 2, further comprising:

a plurality of switching means which respectively correspond to the plurality of droplet ejection heads; and

detection determining means that determines for which droplet ejection head the residual vibration detecting means detects the residual vibration;

wherein the corresponding switching means switches a connection of the actuator from the driving circuit to the residual vibration detecting means after carrying out the driving operation of the actuator of the droplet ejection head determined by the detection determining means.

42. The droplet ejection apparatus as claimed in claim 1 or 2, wherein the residual vibration detecting means includes an

oscillation circuit and the oscillation circuit oscillates in response to an electric capacitance component of the actuator that varies with the residual vibration of the diaphragm or in response to an electromotive voltage component of the actuator.

43. The droplet ejection apparatus as claimed in claim 42, wherein the ejection failure detecting means includes a resistor element connected to the actuator, and the oscillation circuit forms a CR oscillation circuit based on the electric capacitance component of the actuator and a resistance component of the resistor element.

44. The droplet ejection apparatus as claimed in claim 42, wherein the ejection failure detecting means includes an F/V converting circuit that generates a voltage waveform in response to the residual vibration of the diaphragm from a predetermined group of signals generated based on changes in an oscillation frequency of an output signal from the oscillation circuit.

45. The droplet ejection apparatus as claimed in claim 44, wherein the ejection failure detecting means includes a waveform shaping circuit that shapes the voltage waveform in response to the residual vibration of the diaphragm generated by the F/V converting circuit into a predetermined waveform.

46. The droplet ejection apparatus as claimed in claim 45, wherein the waveform shaping circuit includes: DC component eliminating means for eliminating a direct current component from the voltage waveform of the residual vibration of the diaphragm generated by the F/V converting circuit; and a comparator that compares the voltage waveform from which the direct current component thereof has been eliminated by the DC component eliminating means with a predetermined voltage value;

wherein the comparator generates and outputs a rectangular wave based on this voltage comparison.

47. The droplet ejection apparatus as claimed in claim 1, wherein the actuator includes an electrostatic actuator.

48. The droplet ejection apparatus as claimed in claim 1 or 2, wherein the actuator includes a piezoelectric actuator having a piezoelectric element and using a piezoelectric effect of the piezoelectric element.

49. The droplet ejection apparatus as claimed in claim 1 or 2, wherein the droplet ejection apparatus includes an ink jet printer.

50. A method of detecting and judging a head failure in a droplet ejection apparatus, the method comprising the steps of:

detecting a residual vibration of a diaphragm displaced by an actuator in a droplet ejection head after the actuator has been driven by a driving circuit;

generating reference pulses at the same time when detecting the residual vibration of the diaphragm;

carrying out an operation for the number of reference pulses generated on the basis of the residual vibration of the diaphragm;

measuring a lapsed time since the actuator has been driven by the driving circuit; and

judging a head failure in the droplet ejection head on the basis of the computation result and the measured lapsed time.

51. A method of detecting and judging a head failure in a droplet ejection apparatus, the method comprising the steps of:

detecting a residual vibration of an electromotive voltage generated from an actuator in a droplet ejection head after the actuator has been driven by a driving circuit;

generating reference pulses at the same time when detecting the residual vibration of the electromotive voltage;

carrying out an operation for the number of reference pulses generated on the basis of the residual vibration of the

electromotive voltage;

measuring a lapsed time since the actuator has been driven by the driving circuit; and

judging a head failure in the droplet ejection head on the basis of the computation result and the measured lapsed time.

52. The method as claimed in claim 50 or 51, further comprising the step of:

carrying out recovery processing to eliminate a cause of the head failure in response to the judged cause of the head failure.